STOCHASTIC PATTERN OF TRAFFIC ACCIDENTS IN BANDUNG CITY

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This paper deals with a study to gain a better understanding about traffic accident phenomena in Bandung City, the capital of West Java. The principal concern, which is very important for traffic management, is on the following traffic accident parameters; daily accident rate, daily accident-hazard-level, probability of daily fatal accidents and daily fatal victim rates. This study includes data collection and summarization, which will be used to estimate those parameters by using the following three stochastic models; Generalized Poisson (GP) distribution to explain the first two parameters, Generalized Poisson-Quasi Binomial (GPQB) distribution and Generalized Poisson-Generalized Poisson (GPGP) distribution to explain respectively the third and the fourth parameters. A goodness of fit test will show the significance of those models and some important results will be discussed.

Key Words: Accident rate, Accident-hazard-level, Fatal accident, Fatal victim rate, Goodness of fit test

1. INTRODUCTION

1.1 Background and objective

The success of economic development in Indonesia during the three decades, 1967–1997, on the one hand had increased the quality of life including the quality, and the quantity, of road traffic devices and vehicles. On the other hand, people were very anxious about the unexpected negative side effects of transportation development such as road traffic accidents, fatal accidents, fatal victims, etc. In Bandung City, the capital of West Java, it seems that during the period of January 1990 – May 1993 the quantity and quality of those unexpected effects had been decreasing from year to year. Even though, the loss to the society caused by traffic accidents cannot be neglected and thus strong efforts are needed to reduce that loss toward a "zero defect" condition.

The number of road traffic accidents in big cities in Indonesia, as reported by the mass media, has increased the level of anxiety. It is important for the authority in traffic management to have a better understanding about the pattern of that unexpected phenomenon in order to be able to make good policies and to take necessary actions for reducing the quantity and quality of traffic accidents. In this paper we are concerned about the following four basic parameters of traffic accident phenomena: (1) daily accident rate, which indicates the intensity of the basic change process; (2) daily accident-hazard-level indicating the intensity of many hazards in the occurrence of traffic accidents; (3) probability of daily fatal accidents; and (4) daily fatal victim rate.

To conduct a study about the behavior of these parameters, stochastic models will be used. First of all, we use the GP distribution model given in Consul[1] and Consul and Jain[2] to explain the first two parameters. Later on, we use the GPQB and GPGP distributions given in Shanmungan and Singh[3] to explain respectively the third and the fourth parameters. Using these models, we expect to achieve at least three objectives.

1. Ability to explain accurately the above parameters;
2. Ability to estimate those parameters for Bandung City based on actual data;
3. Ability to ensure the accuracy of the model by conducting a goodness of fit test.

1.2 Basic assumptions

We start with the following basic assumptions:

1. The accident rate is not constant in every interval of time of the same length. It varies depending upon many hazards such as traffic intensity, road condition, traffic light condition, driver condition, vehicle condition, etc. In other words, that assumption does account for the variability as a consequence of traffic hazards;

2. We accept the notion of fatalities in road traffic accidents defined by Bandung City Police Department (BCPD);
3. The term fatality will be limited to fatal accidents and fatal victims.

1.3 Methodology

According to the above assumptions, the following methodology is used.

1. Survey on written documents and other resources and discuss it with resource people at BCPD;
2. Data collection and tabulation;
3. Stochastic modeling;
4. Estimate all parameters involved in the models;
5. Conduct a goodness of fit test.

The third topic will be presented in Section 2 while the remaining four will be discussed in Section 3. Finally, important results will be discussed in Section 4.

2. STOCHASTIC MODELING

2.1 Generalized Poisson model

Let X be the random variable representing the number of traffic accidents in a region of study in a given interval of time. If we focus on the accident rate parameter only, which is equivalent to the assumption that accidents occur in random pattern, then the appropriate way to study X is by using the Poisson process. But, if in describing X we have to take into account many hazards such as traffic density, road condition, traffic light condition, driver condition, vehicle condition, etc, the Poisson process is not adequate. To study this topic, in what follows we use the following limitation; all those traffic hazards will be unified in a parameter called accident-hazard-level.

Let us denote $\mathcal{A} = \{0, 1, 2, ...\}$ the space of all possible outcomes of X. If θ and λ represent accident rate and accident-hazard-level respectively, the distribution of X has the following probability density function, see Consul[1] and Consul and Jain[2] for further details,

$$f(x) = \frac{\theta(\theta+x\lambda)^{x-1}}{x!}\exp\{-(\theta+x\lambda)\} \quad \text{.................................} \quad (1)$$

where x is in $\mathcal{A}$, $\theta > 0$ and max $(-1, -\theta/m) < \lambda \leq 1$ with m as the largest positive integer for which $\lambda + \theta m > 0$. The mean and variance of X are respectively,

$$\mu_x = \theta(1-\lambda)^{-1} \text{ and } \sigma_x^2 = \theta(1-\lambda)^{-3} \quad \text{..................................} \quad (2)$$

We see that, if $\lambda = 0$, X follows Poisson distribution with parameter θ and thus in this case $\theta = \mu_x = \sigma_x^2 > 0$. Further details about Poisson distribution can be seen, for example, in Bath[4] and Bartholomew[5]. In general, if $\lambda \neq 0$, the relationship between the mean and variance of X is as follows,

1. If $0 < \lambda < 1$, then $0 < \theta < \mu_x < \sigma_x^2$.
2. For $\lambda < 0$, we have $\theta > \mu_x > \sigma_x^2 > 0$.

According to this relationship, $\lambda = 0$ indicates the phenomenon where "no effort" is done by road users to avoid an accident. In other words, an accident occurs in a random pattern or really by accident. On the other hand, $\lambda < 0$ indicates that there was an effort to avoid an accident. There exists a certain pattern of the behavior of road users in reducing the number of traffic accidents. Conversely, $\lambda > 0$ indicates the situation which allows the increase of the number of accidents. The larger the value of $\lambda > 0$, the higher the level of many hazards in increasing the number of traffic accidents in the region of study. The random variable X having probability density function in Equation (1) is called to follow the Generalized Poisson distribution with two parameters θ and λ and we write briefly $X \sim GP(\theta, \lambda)$.

Although that distribution has the ability to explain the accident rate and accident-hazard-level, it still has a drawback in explaining the fatality phenomenon. In the next two sections we accept the notion of fatalities in road traffic accidents defined by BCPD. Furthermore, the term fatality will be limited into fatal accidents and fatal victims. In the former case we are concerned about the probability of fatal accidents while in the latter case, our concern is on the fatal victim rate.

2.2 Probability of fatal accident

Consider again the random variable X mentioned previously. For a given value of X, say X = x, suppose Y is the number of fatal accidents. It is clear that the space of Y is $\mathcal{B} = \{0, 1, 2, \ldots, x\}$. In order to be able to explain the probability that an accident is fatal, in this subsection we will study the distribution of Y. Let us start by identifying the conditional distribution of Y given X = x. For this purpose, we define independent random variables $Y_1, Y_2, \ldots, Y_x$ as follows,

$$Y_i = \begin{cases} 1, & \text{if the i-th accident is fatal} \\ 0, & \text{otherwise} \end{cases}$$

Thus $Y = \sum_{i=1}^{x} Y_i$. If $P(Y_i = 1) = p$ does not depend on i, Shanmungan and Singh[3] give the following conditional probability density function of Y given X = x,

$$g(y|x) = C_y^x \frac{\theta pq}{\theta+x\lambda}\left\{\frac{\theta p+y\lambda}{\theta+x\lambda}\right\}^{y-1}\left\{\frac{\theta q+(x-y)\lambda}{\theta+x\lambda}\right\}^{x-y-1} \quad \text{........ (3)}$$

where x in $\mathcal{A}$, y in $\mathcal{B}$, $0 < p < 1$, $q = 1 - p$ and C_y^x is the combination of y objects drawn from x objects. For further details about this conditional distribution, the reader can consult Shanmungan and Singh[3]. This conditional distribution, see Bath[4], will become a binomial distribution with parameter x and p if $\lambda = 0$. In fact, for $\lambda = 0$, we have,

$$g(y|x) = C_y^x p^y q^{x-y} \ ; \ y = 0, 1, 2, \ldots, x$$

To derive the marginal distribution of Y we first determine the joint probability density function $\varphi(x,y) = g(y|x)f(x)$ of X and Y where f(x) is given in Equation (1). From Equations (1) and (3) we obtain,

$$\varphi(x,y) =$$
$$= \frac{x!}{(x-y)!y!}\frac{\theta pq}{\theta+x\lambda}\left\{\frac{\theta p+y\lambda}{\theta+x\lambda}\right\}^{y-1}\left\{\frac{\theta q+(x-y)\lambda}{\theta+x\lambda}\right\}^{x-y-1}\frac{\theta(\theta+x\lambda)^{x-1}}{x!}\exp\{-(\theta+x\lambda)\}$$
$$= \frac{\theta^2 pq(\theta p+y\lambda)^{y-1}(\theta q+(x-y)\lambda)^{x-y-1}}{(x-y)!y!(\theta+x\lambda)^{x-1}}(\theta+x\lambda)^{x-1}\exp\{-(\theta+x\lambda)\}$$
$$= \theta^2 pq(\theta p+y\lambda)^{y-1}\{(\theta q+(x-y)\lambda)\}^{x-y-1}\frac{\exp\{-(\theta+x\lambda)\}}{(x-y)!y!} \quad \text{...................... (4)}$$

where x in $\mathcal{A}$, y in $\mathcal{B}$, $0 < p < 1$, and $\theta + y\lambda > 0$. This bivariate random variable (X, Y) is called Generalized Poisson-Quasi Binomial distribution with parameters θ, λ and p or briefly GPQB(θ, λ, p). Now, from Equation (4) we obtain the following marginal probability density function of Y,

$$\varphi_Y(y) = \sum_{x=0}^{\infty}\varphi(x, y)$$
$$= \frac{\theta p(\theta p+y\lambda)^{y-1}}{y!}\exp\{-(\theta p+y\lambda)\}$$

where y = 0, 1, 2, … and $\theta + y\lambda > 0$. This shows that Y ~ GP(θp, λ) and consequently the mean and variance of Y are respectively,

$$\mu_y = \theta p(1-\lambda)^{-1} \text{ and } \sigma_y^2 = \theta p(1-\lambda)^{-3} \quad \text{.............................. (5)}$$

2.3 Fatal victim rate

Given the number of traffic accidents X = x in a region of study in a given interval of time where X ~ GP(θ, λ), we consider the random variable Z_i, which represents the number of fatal victims in the i-th accident; i = 1, 2, … , x. The space of Z_i is equal to the space of X i.e., $\mathcal{A} = \{0, 1, 2, ...\}$. If $\eta > 0$ denotes the fatal victim rate, which does not depend on i, by using the same argument as for X, then Z_i ~ GP(η, λ). It is thus reasonable to assume that for a given value of X, say X = x, the random variables $Z_1, Z_2, \ldots, Z_x$ are independent. Let Z represent the total number of fatal victims if X = x, i.e., $Z = \sum_{i=1}^{x} Z_i$. The conditional distribution of Z given X = x is GP(xη, λ) and hence, its probability density function is,

$$h(z|x) = \frac{x\eta(x\eta+z\lambda)^{z-1}}{z!}\exp\{-(x\eta+z\lambda)\} \quad \text{...................... (6)}$$

where z in $\mathcal{A}$ and $x\eta + z\lambda > 0$. Now, from Equation (6), we obtain the following joint probability density function of X and Z,

$$\phi(x,z) = h(z|x).f(x)$$
$$= \theta\eta(\theta+x\lambda)^{x-1}(x\eta+z\lambda)^{z-1}\frac{\exp\{-(\theta+x\lambda+x\eta+z\lambda)\}}{(x-1)!z!} \quad \text{.. (7)}$$

where x and z in $\mathcal{A}$, $\theta + x\lambda + x\eta + z\lambda > 0$ and $\phi(0,0)$ = P(Y=0, X=0) for x = 0. This bivariate random variable (X, Z) is called Generalized Poisson-Generalized Poisson distribution with parameters θ, λ and η or shortly GPGP(θ, λ, η). The mean and variance of Z, see Shanmungan and Singh[3], are,

$$\mu_z = \frac{\theta\eta}{(1-\lambda)^2} \text{ and } \sigma_z^2 = \frac{\theta\eta(1-\lambda+\eta)}{(1-\lambda)^2} \quad \text{.............................. (8)}$$

2.4 Parameter estimation

As mentioned in Equations (2), (5) and (8) the mean and variance of X, Y and Z are non-linear functions of θ, λ, η and p. Consequently, the maximum likelihood method to estimate those parameters will give a complicated system of equations. Thus, instead of using that method, we use the moment method. For this purpose, let $X_1, X_2, \ldots, X_n$ and $Y_1, Y_2, \ldots, Y_m$ and $Z_1, Z_2, \ldots, Z_k$ be random samples respectively of size n, m and k from X, Y and Z. The sample means,

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n}X_i,\ \overline{Y} = \frac{1}{m}\sum_{i=1}^{m}Y_i \text{ and } \overline{Z} = \frac{1}{k}\sum_{i=1}^{k}Z_i$$

are unbiased estimators of μ_x, μ_y and μ_z respectively. Furthermore, the sample variances,

$$s_x^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i-\overline{X})^2,\ s_y^2 = \frac{1}{m-1}\sum_{i=1}^{m}(Y_i-\overline{Y})^2 \text{ and } s_z^2 = \frac{1}{k-1}\sum_{i=1}^{k}(Z_i-\overline{Z})^2$$

are also unbiased estimators of σ_x^2, σ_y^2 and σ_z^2. To use moment method, it is sufficient to construct the following system of four equations,

$$\begin{cases} \overline{X} = \dfrac{\hat{\theta}}{1-\hat{\lambda}} \\ s_x^2 = \dfrac{\hat{\theta}}{(1-\hat{\lambda})^3} \\ \overline{Y} = \dfrac{\hat{\theta}\hat{p}}{1-\hat{\lambda}} \\ \overline{Z} = \dfrac{\hat{\theta}\hat{\eta}}{(1-\hat{\lambda})^2} \end{cases} \quad \text{.......} \quad (9)$$

and then solve it to obtain the estimators $\hat{\theta}$, $\hat{\lambda}$, $\hat{\eta}$ and $\hat{p}$ respectively of θ, λ, η and p. The solution of that system of equations is,

$$\hat{\theta} = \overline{X}(1-\hat{\lambda}),\ \hat{\lambda} = 1-\frac{\sqrt{\overline{X}}}{s_x},\ \hat{\eta} = \frac{\overline{Z}(1-\hat{\lambda})^2}{\hat{\theta}},\ \text{and } \hat{p} = \frac{\overline{Y}}{\overline{X}} \quad \text{....} \quad (10)$$

3. IMPLEMENTATION OF MODEL

3.1 Data collection

The implementation of those models mentioned previously is limited for daily accident data collected from the period of January 1990 until May 1993 and the region of study is Bandung City. The accidents to be studied were those involving motorized vehicles. Data about daily road traffic accidents in Bandung City were very well recorded by the police officers at BCPD (or also known as POLWILTABES Bandung). They provided us with Unpublished Reports[6] containing useful data for this study. We have tabulated it and the results are shown in Tables 1–3. It is important to note that Table 2 is not complete because data of Y = k given X = x, for $1 \le k \le x$ and x = 2, 3, … , are not available. In these tables, X, Y and Z represent the number of daily accidents, the number of daily fatal accidents, and the number of daily fatal victims respectively.

Table 1 Number of daily accidents

Number of accidents X	Number of days in 1990	1991	1992	1993
0	27	89	163	96
1	52	111	119	44
2	83	92	55	9
3	76	48	20	1
4	66	18	8	1
5	37	6	1	0
6	16	1	0	0
7	4	0	0	0
8	4	0	0	0
Total	365	365	366	151

Table 2 Number of daily fatal accidents

Year	Number of fatal accidents	Number of days with X = 0	1	2	3	4	5	6	7	8	Total
1990	Y = 0	27	36	49	30	15	9	4	0	1	171
	Y > 0		16	34	46	51	28	12	4	3	194
1991	Y = 0	89	95	57	26	8	4	0			279
	Y > 0		16	35	22	10	2	1			86
1992	Y = 0	163	88	40	9	7	0				307
	Y > 0		31	15	11	1	1				59
1993	Y = 0	96	21	7	0	0					124
	Y > 0		23	2	1	1					27

Table 3 Number of daily fatal victims

Year	Number of fatal victims	Number of days with X = 0	1	2	3	4	5	6	7	8	Total
1990	Z=0	27	36	49	30	15	9	4	0	1	171
	Z=1		14	25	38	40	26	8	1	2	154
	Z=2		2	6	4	7	2	3	1	1	26
	Z=3		0	1	4	2	0	1	2	0	10
	Z=4		0	2	0	2	0	0	0	0	4
1991	Z=0	89	95	57	26	8	4	0			279
	Z=1		13	26	19	9	2	0			69
	Z=2		3	7	3	1	0	1			15
	Z=3		0	2	0	0	0	0			2
1992	Z=0	163	88	40	9	7	0				304
	Z=1		25	13	8	0	1				47
	Z=2		6	2	2	1	0				11
	Z=3		0	0	1	0	0				1
1993	Z=0	96	21	7	0	0					124
	Z=1		22	0	1	1					24
	Z=2		1	2	0	0					3

3.2 Parameter estimate

First, we calculate $\overline{X}$, s_x, $\overline{Y}$ and $\overline{Z}$ and then substitute its values to Equation (10) to obtain the estimate $\hat{p}$, $\hat{\lambda}$, $\hat{\theta}$ and $\hat{\eta}$. Here we use the same symbol for the estimate and estimator. From Tables 1–3 we obtained the value of those statistics from year to year as can be seen in Table 4. It is important to note that, due to the unavailability of data of Y = k given X = x for $1 \le k \le x$ and x = 2, 3, … as mentioned previously, in Table 4 the value of $\overline{Y}$ is calculated by using data in Table 2 and the center point between 1 and x for each value of x. Finally, by using the statistics in Table 4 and Equation (10), in Table 5 we present the estimates $\hat{\theta}$, $\hat{\lambda}$, $\hat{\eta}$ and $\hat{p}$ from year to year.

3.3 Goodness of fit test for GP model

In this sub-section we tested the goodness of fit of

Table 4 Statistics $\overline{X}$, s_x, $\overline{Y}$ and $\overline{Z}$

Statistic	Year 1990	1991	1992	1993
$\overline{X}$	2.87945	1.49863	0.89071	0.45695
s_x	1.69898	1.24615	1.02252	0.69986
$\overline{Y}$	1.21096	0.40274	0.22131	0.20199
$\overline{Z}$	0.69041	0.28767	0.19672	0.19868

Table 5 Estimates $\hat{\theta}$, $\hat{\lambda}$, $\hat{\eta}$ and $\hat{p}$

Estimate	Year 1990	1991	1992	1993
$\hat{\theta}$	2.87591	1.47222	0.82211	0.44137
$\hat{\lambda}$	0.00123	0.01762	0.07702	0.03411
$\hat{\eta}$	0.23948	0.18857	0.20385	0.41995
$\hat{p}$	0.42055	0.26873	0.24847	0.44203

the distribution of X, which is the basic model, by using the chi-square distribution. For this purpose, the value of $\hat{\theta}$ and $\hat{\lambda}$ in Table 5 are substituted into the basic model i.e., Equation (1) to obtain the estimate of $P(X = x)$ in each year of observations 1990, 1991, 1992 and the first five months of 1993 where $x = 0, 1, 2, \ldots$. Furthermore, to obtain the expected number of daily accidents, we multiplied that estimate of $P(X = x)$ with the number of days in each of those years. The results are presented in Table 6 under the heading "Exp". This expected value "Exp" together with observed value "Obs" will be used to test the goodness of fit of the model.

To test the significance of Equation (1), we calculated the chi-square statistic based on O = "Obs" and E = "Exp". More specifically, chi-square statistic is equal to the sum of $(O - E)^2/E$ where summation is over all possible values of x. We see in Table 6 that, at the 5% level of significance, the chi-square value is less than the critical point (CP) for each year of observation. This means that the basic model in Equation (1) significantly fits the data from the field.

3.4 Goodness of fit test for GPQB model

It is not possible to conduct a goodness of fit test for model GPQB in Equation (4) because of the lack of data $Y = k$ given $X = x$ for $1 \le k \le x$ and $x = 2, 3, \ldots$. Thus, instead of working on X and Y, we limited ourselves on the joint distribution of X and U where the random variable U is defined by $U = 0$ if $Y = 0$ and $U = 1$ if $Y > 0$. In this case, the conditional probability density function of U given X is,

$$G(u|x) = \begin{cases} 1;\ u = x = 0 \\ g(0, x);\ u = 0,\ x = 1, 2, \ldots \\ 1 - g(0, x);\ u = 1,\ x = 1, 2, \ldots \end{cases}$$

where $g(0|x)$ is given by Equation (3). By using Equations (1), (3) and (4), it can be shown that the joint probability density function $\xi(x, u) = G(u|x)f(x)$ of U and X is,

$$\xi(x, u) = \begin{cases} \exp(-\theta);\ u = x = 0 \\ \theta(1-p)\{\theta(1-p)+x\lambda\}^{x-1}\dfrac{\exp\{-(\theta+x\lambda)\}}{x!};\ u = 0,\ x = 1, 2, \ldots \\ f(x) - \xi(x, 0);\ u = 1,\ x = 1, 2, \ldots \end{cases} \quad \ldots\ldots\ldots\ldots (11)$$

Instead of testing the goodness of fit for model GPQB, we test the model for $\xi(x,u)$ in Equation (11) by using the similar method described in sub-section 3.3. In Table 7 we present the expected number of events $U = 0$ and $U = 1$ for all possible values of x, chi-square statistic and the corresponding 5% CP. That table shows that the model (11) for $\xi(x,u)$ fits significantly the data in 1992 and 1993 but not 1990 and 1991.

3.5 Goodness of fit test for GPGP model

In Tables 8a–8d we present the expected number of daily fatal victims, chi-square statistic and the corresponding 5% CP. The value of chi-square and the corresponding 5% CP, summarized in Table 9, show that the model GPGP fits significantly the data in 1991 and 1992 but not in 1990 and 1993.

Table 6 Observed (Obs) and Expected (Exp) number of daily accidents, chi-square and 5% Critical Point (CP)

Number of accidents X	1990 Obs	1990 Exp	1991 Obs	1991 Exp	1992 Obs	1992 Exp	1993 Obs	1993 Exp
0	27	20.57	89	83.74	163	161.02	96	97.12
1	52	59.09	111	121.13	119	122.41	44	41.43
2	83	84.94	92	89.70	55	55.26	9	10.20
3	76	81.47	48	45.33	20	19.36	1	1.91
4	66	58.65	18	17.58	8	5.83	1	0.30
5	37	33.81	6	5.58	1	1.59	0	0
6	16	16.25	1	1.51	0	0	0	0
7	4	6.70	0	0	0	0	0	0
8	4	2.42	0	0	0	0	0	0
Chi-square	6.61		1.61		1.17		2.37	
CP	14.07		11.07		9.49		7.81	

Table 7 Expected (Exp) number of daily fatal accidents, chi-square and 5% Critical Point (CP)

Number of days with X	1990 Y=0	1990 Y>0	1991 Y=0	1991 Y>0	1992 Y=0	1992 Y>0	1993 Y=0	1993 Y>0
0	20.57		83.74		160.86		97.12	
1	34.24	24.85	88.57	32.55	92.02	30.42	23.11	18.31
2	28.54	56.40	48.38	41.32	32.88	22.45	3.51	6.69
3	15.88	65.59	18.18	27.15	9.47	9.93	0.44	1.47
4	6.64	52.02	5.28	12.29	2.42	3.43	0.05	0.25
5	2.22	31.59	1.27	4.31	0.57	1.02		
6	0.62	15.63	0.26	1.25				
7	0.15	6.5						
8	0.03	2.39						
Chi-square	115.21		25.34		15.36		11.01	
CP	23.68		18.31		15.51		12.59	

Table 8a Expected number of daily fatal victims, chi-square and 5% Critical Point (CP) for 1990

Year	Number of days with X=	Z=0	Z=1	Z=2	Z=3	Z=4
1990	0	20.57				
	1	46.51	11.12	1.34	0.11	0.01
	2	52.62	25.17	6.05	0.97	0.12
	3	39.72	28.50	10.26	2.47	0.45
	4	22.50	21.53	10.33	3.31	0.80
	5	10.21	12.21	7.32	2.93	0.00
	6	3.86	5.54	3.99	1.91	0.69
	7	1.25	2.10	1.76	0.99	0.41
	8	0.36	0.68	0.65	0.42	0.20
Chi-square		101.32				
CP		53.38				

Table 8b Expected number of daily fatal victims, chi-square and 5% Critical Point (CP) for 1991

Year	Number of days with X=	Z=0	Z=1	Z=2	Z=3
1991	0	83.74			
	1	100.31	18.55	2.04	0.17
	2	61.52	22.80	4.62	0.68
	3	25.74	14.31	4.22	0.88
	4	8.27	6.13	2.38	0.64
	5	2.17	2.01	0.97	0.32
	6	0.49	0.54	0.31	0.12
Chi-square		18.58			
CP		33.92			

Table 8c Expected number of daily fatal victims, chi-square and 5% Critical Point (CP) for 1992

Year	Number of days with X=	Z=0	Z=1	Z=2	Z=3
1992	0	160.86			
	1	99.86	18.85	3.12	0.51
	2	36.80	13.89	3.61	0.81
	3	10.53	5.96	2.11	0.60
	4	2.59	1.95	0.88	0.31
	5	0.57	0.54	0.29	0.12
Chi-square		20.84			
CP		28.87			

Table 8d Expected number of daily fatal victims, chi-square and 5% Critical Point (CP) for 1993

Year	Number of days with X=	Z=0	Z=1	Z=2
1993	0	97.12		
	1	27.22	11.05	2.61
	2	4.40	3.58	1.57
	3	0.54	0.66	0.42
	4	0.06	0.09	0.08
Chi-square		28.86		
CP		18.31		

Table 9 Chi-square and 5% Critical Point (CP) for goodness of fit test of number of fatal accidents

Year	1990	1991	1992	1993
Chi-square	101.32	18.58	20.84	28.86
CP	53.38	33.92	28.87	18.31

4. DISCUSSION

We find that the model in Equation (1) is very significant for daily accident phenomena in Bandung City. The value of chi-square, see Table 6, is very small relative to the critical point in each year of observation. We are then statistically confident about the model in Equation (1) in its ability to explain the phenomenon involving the following two parameters; daily accident rate and daily accident-hazard-level. Furthermore, from Table 1 we realized that the number of days where accidents occurred had been decreasing from year to year during the period of study. It was so with the number of daily fatal accidents as shown in Table 2. There were 1,075 accidents in 1990 where 690 were fatal. This number was reduced to 574 accidents in 1991 where 208 were fatal. It became 326 accidents in 1992 with 103 fatal and during the first five months of 1993, this number was only 69 accidents with 34 fatal. The maximum number of daily accidents also decreased from 8 accidents in 1990, 6 in 1992, 5 in 1992 and 4 during the first five months of 1993. Even though the number of days with one accident seems to increase from year to year. It is important to note that during that period the number of days with more than one accident was reduced very significantly.

From Table 3 we also see that the number of daily fatal victims had been decreasing from year to year. Surprisingly, only in 1990 we find 12 accidents each with 4 fatal victims and there was no accident with more than 3 fatal victims in 1991, 1992 and the first five months of 1993.

From Table 5 we see that the daily accident rate in Bandung City had been decreasing from year to year. It was equal to 2.87591 in 1990 and 1.47222 in 1991 and 0.82211 in 1992 and only 0.44137 in the first five months of 1993. Surprisingly, those values were accompanied by a small but positive daily accident-hazard-level. The estimate of this parameter equals 0.00123 for 1990 and 0.01762 for 1991 and 0.07702 for 1992 and 0.03411 for the first five months of 1993. Even though traffic management must be careful about the increase of that daily accident-hazard-level, which is positive from year to year. In 1991 that parameter was 14 times larger than in 1990. It becomes 62 times larger in 1992 and in the first five months of 1993 it was 27 times. Those small values indicate that accidents almost occurred haphazardly or almost in a random pattern meaning that there was almost no special effort done by road users to avoid accident.

Due to the lack of appropriate data, goodness of fit of the model GPQB defined by Equation (4) cannot be tested but its substitute, Equation (11) shows its usefulness. It fits significantly the data in 1992 and 1993 but not in 1990 and 1991. Although the situation is as such, some ideas might be very useful for this preliminary research. The probability p, although it is not estimated based on Equation (4) as it should be, was high especially during the first five months of 1993. It was equal to 42.1% in 1990, 26.9% in 1992 and 24.9% in 1992. It increased to 44.2% during the first five months of 1993. More comprehensive understanding about p needs further intensive research.

Concerning the model GPGP, it fits significantly for 1991 and 1992 but not for 1990 and 1993. Even though, the following highlight may invite some ideas. Daily fatal victim rate per accident was high. It fluctuated from 0.23948 in 1990 to 0.18857 in 1991, then to 0.20385 in 1992. During the five months of 1993 it reached the highest value of 0.41995. Were these high values closely related to the speed limit in the city? We have no data about this. If these were so, then the speed limit must be enforced and a campaign about road users' discipline must be intensively conducted. Or was it caused by other factors? Another research to identify the root causes of this phenomenon, including the behavior of road users, is of our concern. At last, but not least, the facility to support traffic management, such as a computer database, needs some improvements at BCPD.

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